Consequences of varying orbital configurations for CLARREO sampling errors.

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I. Simultaneous Nadir Overpasses
   A. Geographic distribution
   B. Temporal distribution
II. Characteristics of simulated brightness temperature data set.
III. Benchmark long-term spatial averages

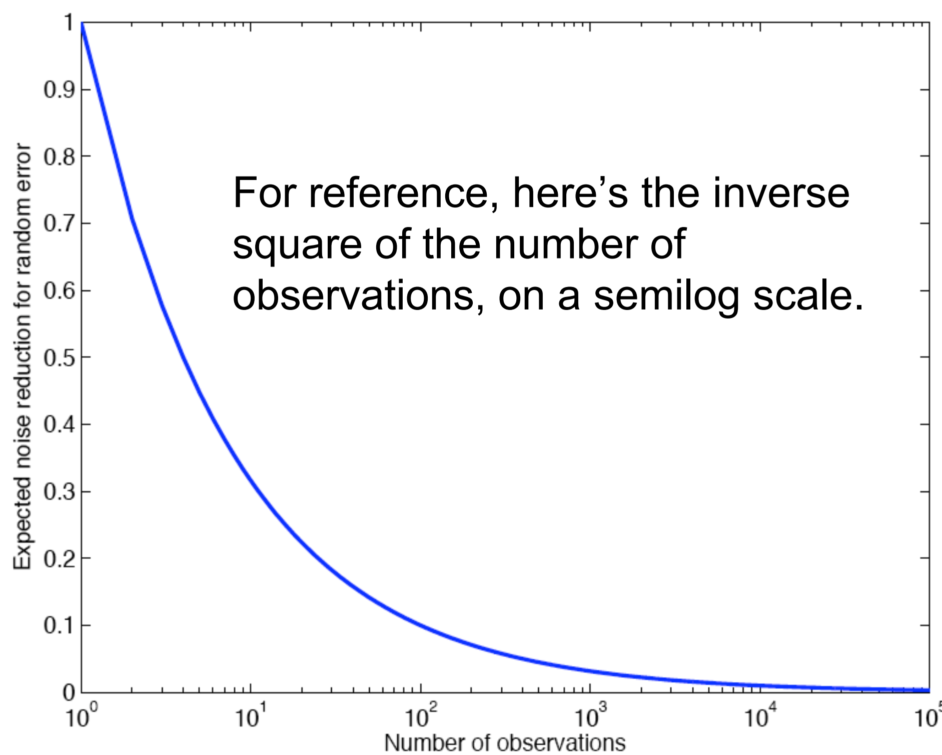
Sampling error for calibration by Simultaneous Nadir Overpasses (SNOs)

For calibration of one satellite by one or more other satellites by simultaneous nadir overpasses, the following sources of error must be taken into account:

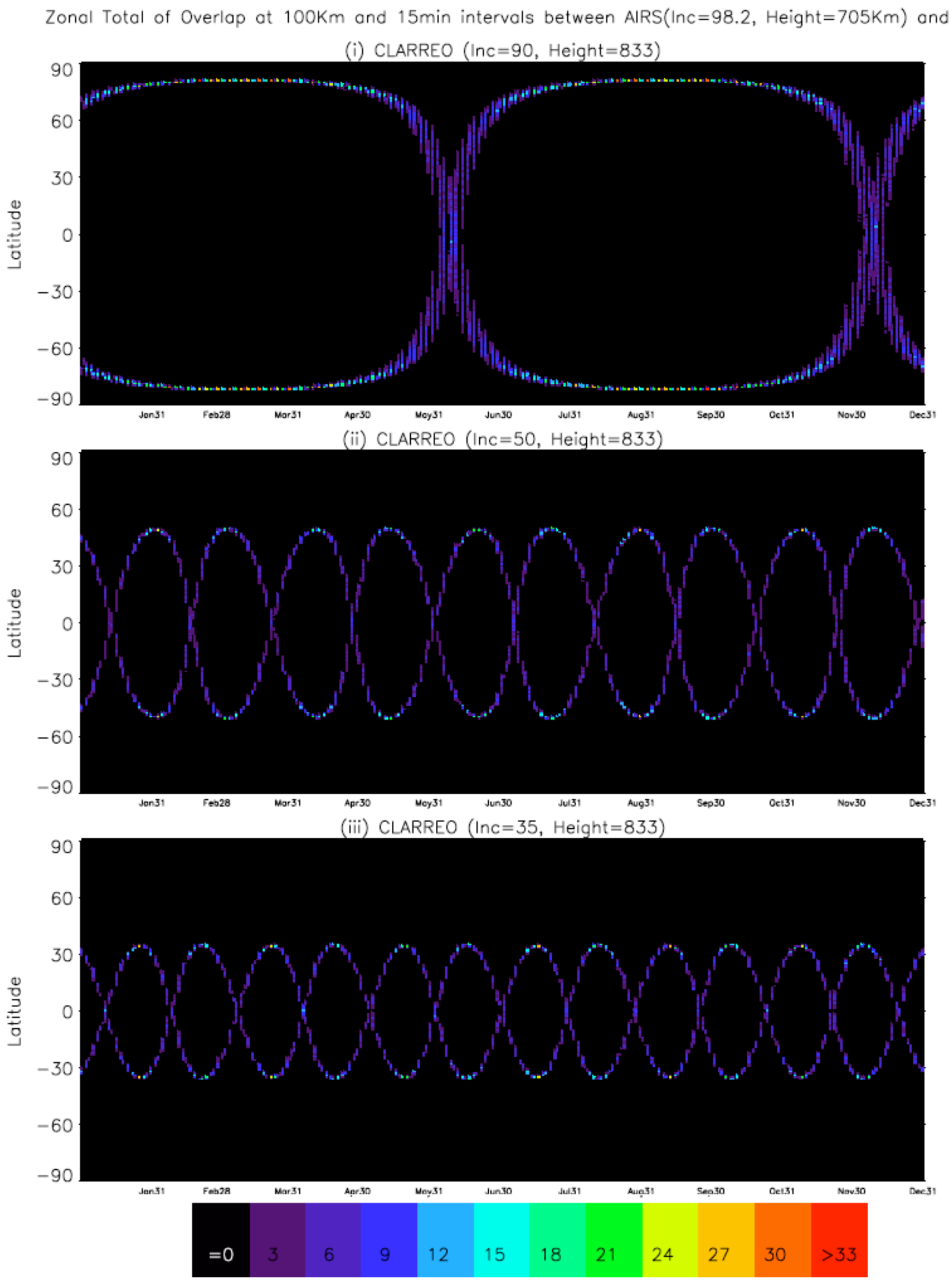
- Instrument noise
- Differences in instrument footprint, in combination with spatial variability of observed field
- Pointing errors

To the extent that all these errors can be treated as random, then all are reduced as the number of observations increases.

Analysis of GOES imagery indicates that a 10 minute error in simultaneity corresponds to about a 2 K error for a 0.5 degree footprint. Errors increase linearly with the time difference.



Temporal and Latitude distribution of SNOs, for temporal mismatches of less than 15 minute and spatial mismatches of less than 100 km

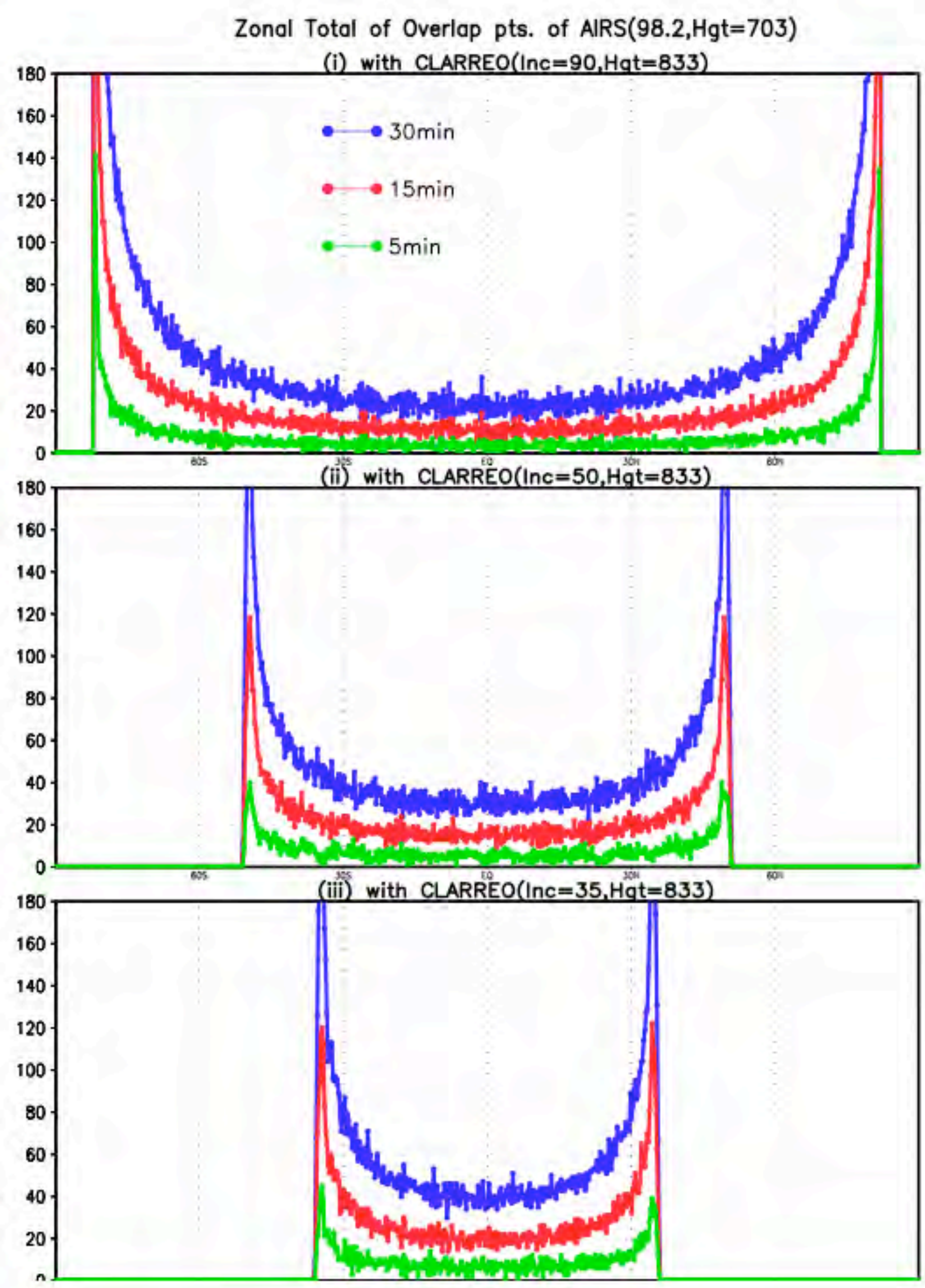


90° polar orbiter

50° orbiter

35° tropical orbiter

Zonal, annual sum of simultaneous overpasses for three orbits, and a range of simultaneity requirements.



90° polar orbiter

50° orbiter

35° tropical orbiter

Assuming we want to partition SNOs into groups having approximately similar brightness temperatures, we will have on the order of 1000 SNOs to work with- reducing all forms of random error by a factor of about 30. Is this sufficient?

Sampling errors calculated using model derived brightness temperatures.

We first investigate the temporal variability of brightness temperature at several frequencies, calculated by applying modtran to archived results of a one year run of the GFDL coupled climate model.
We then sub-sample this data using a range of possible orbits and combinations of orbits to estimate the annual mean sampling error for a range of orbits.

We choose a frequencies that sample a wide range of regions in the atmosphere.

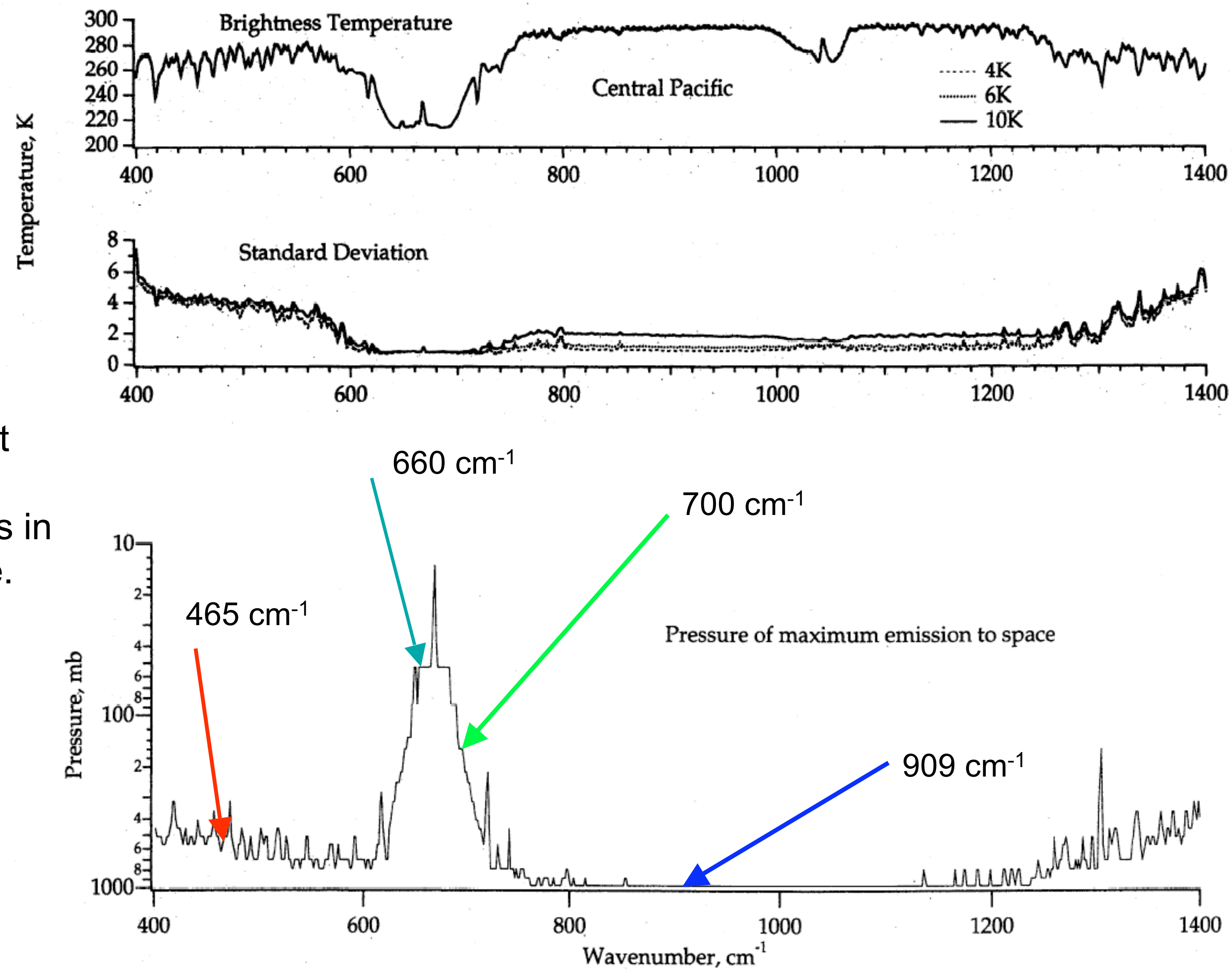
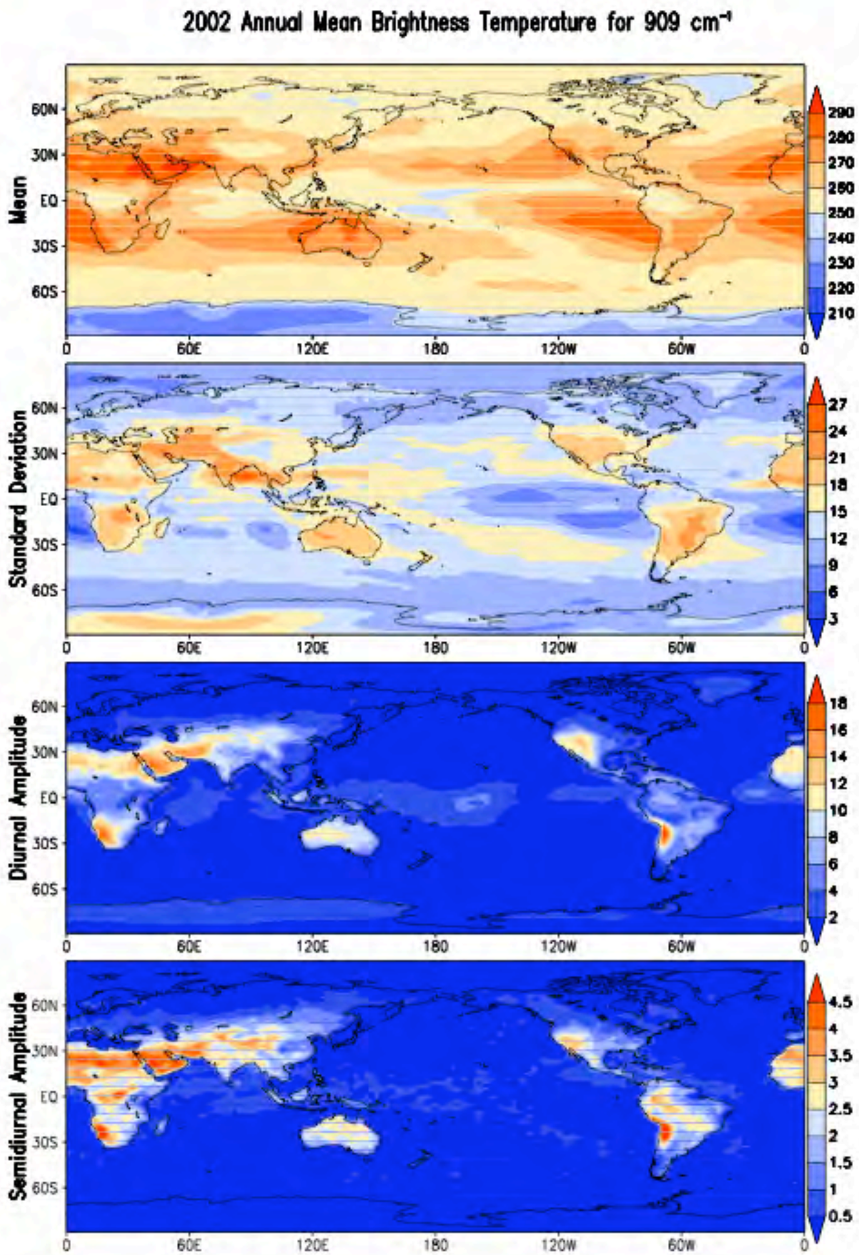
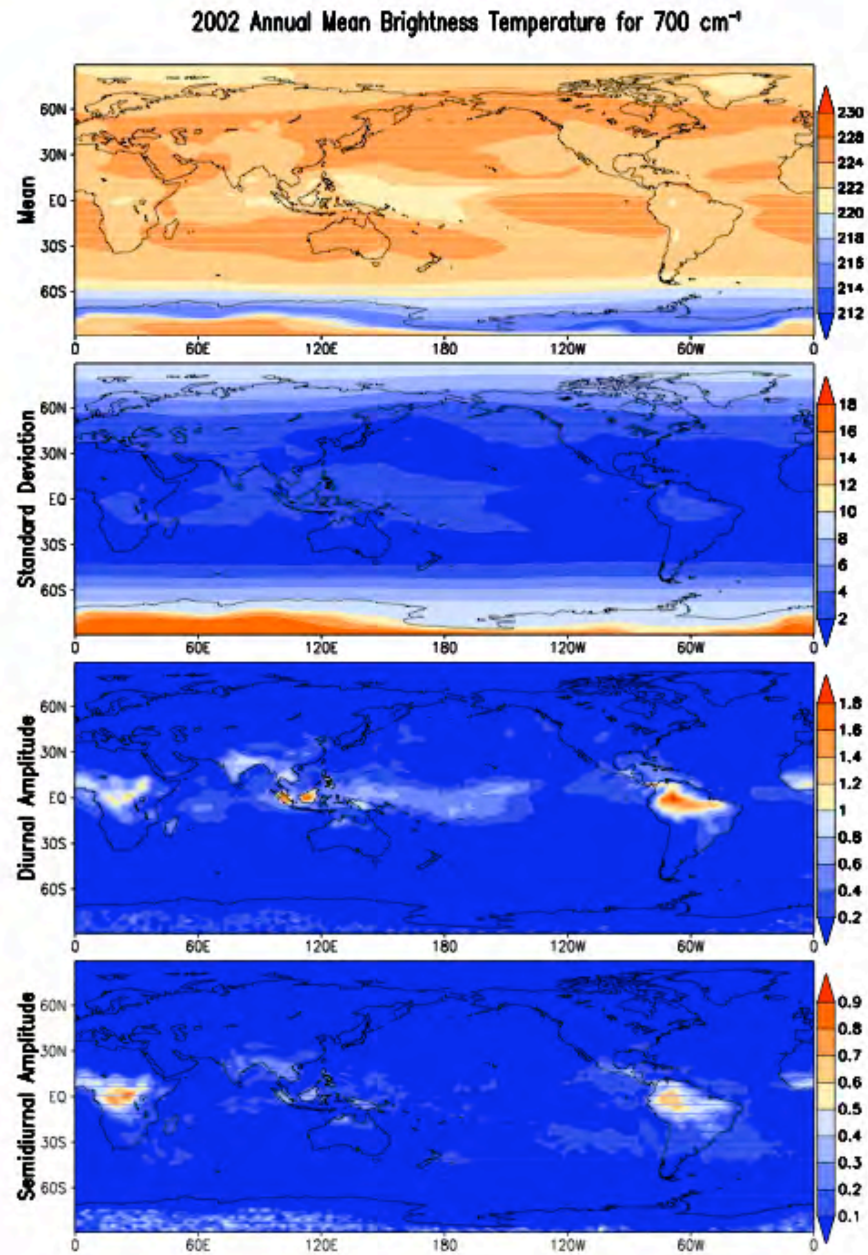


Figure 2. (top) Brightness temperatures measured from the IRIS data and calculated from the GCM data. The spectra are averaged over all 10 months of observations and over three tropical regions. (bottom) The pressure level of the maximum emission to space for each wavenumber calculated using MODTRAN with a standard tropical atmosphere.



Window channel



~250 hPa

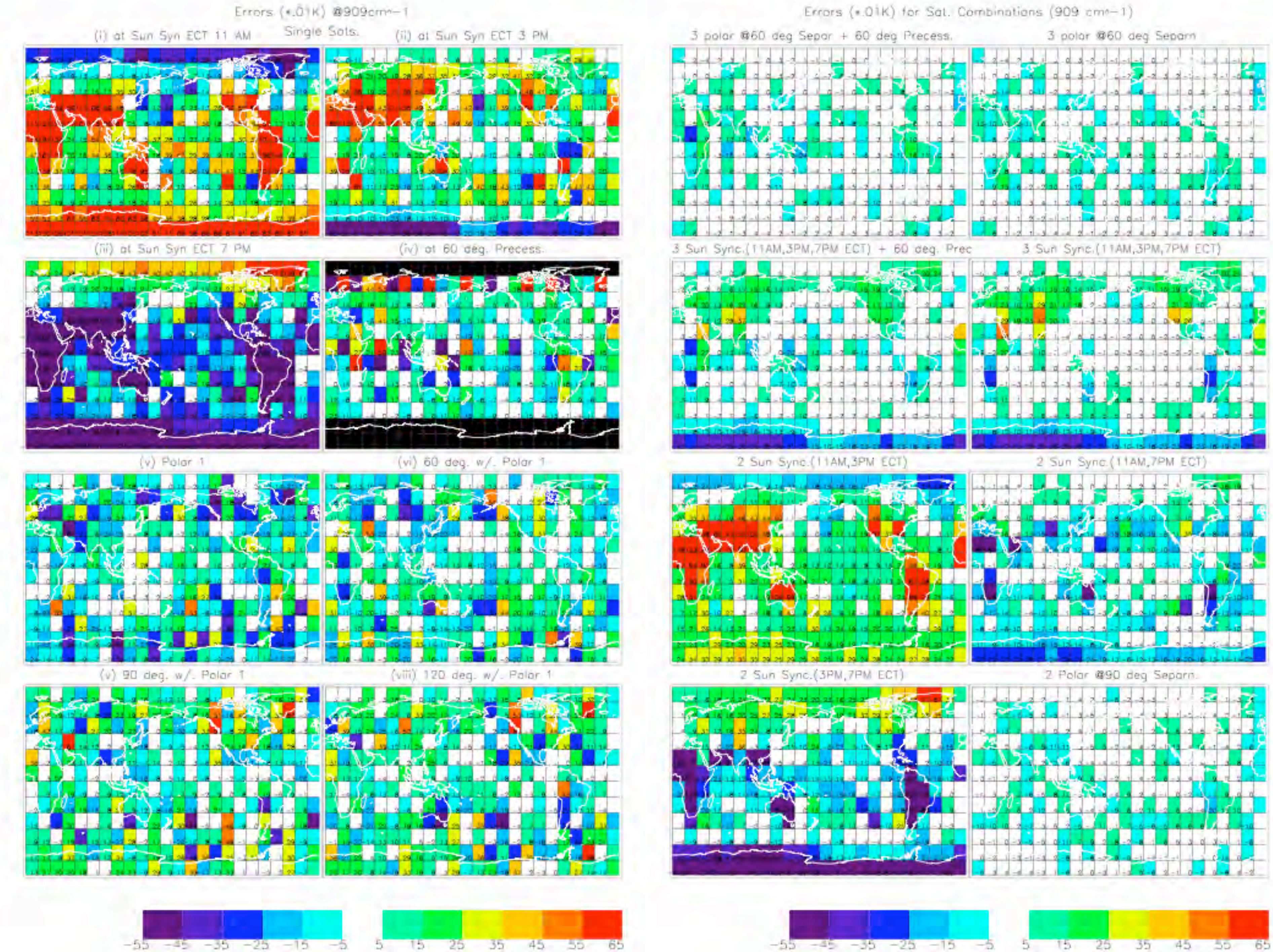
We now create simulated satellite data records by subsampling the modeled brightness temepratures using a number of orbits and combinations of orbits

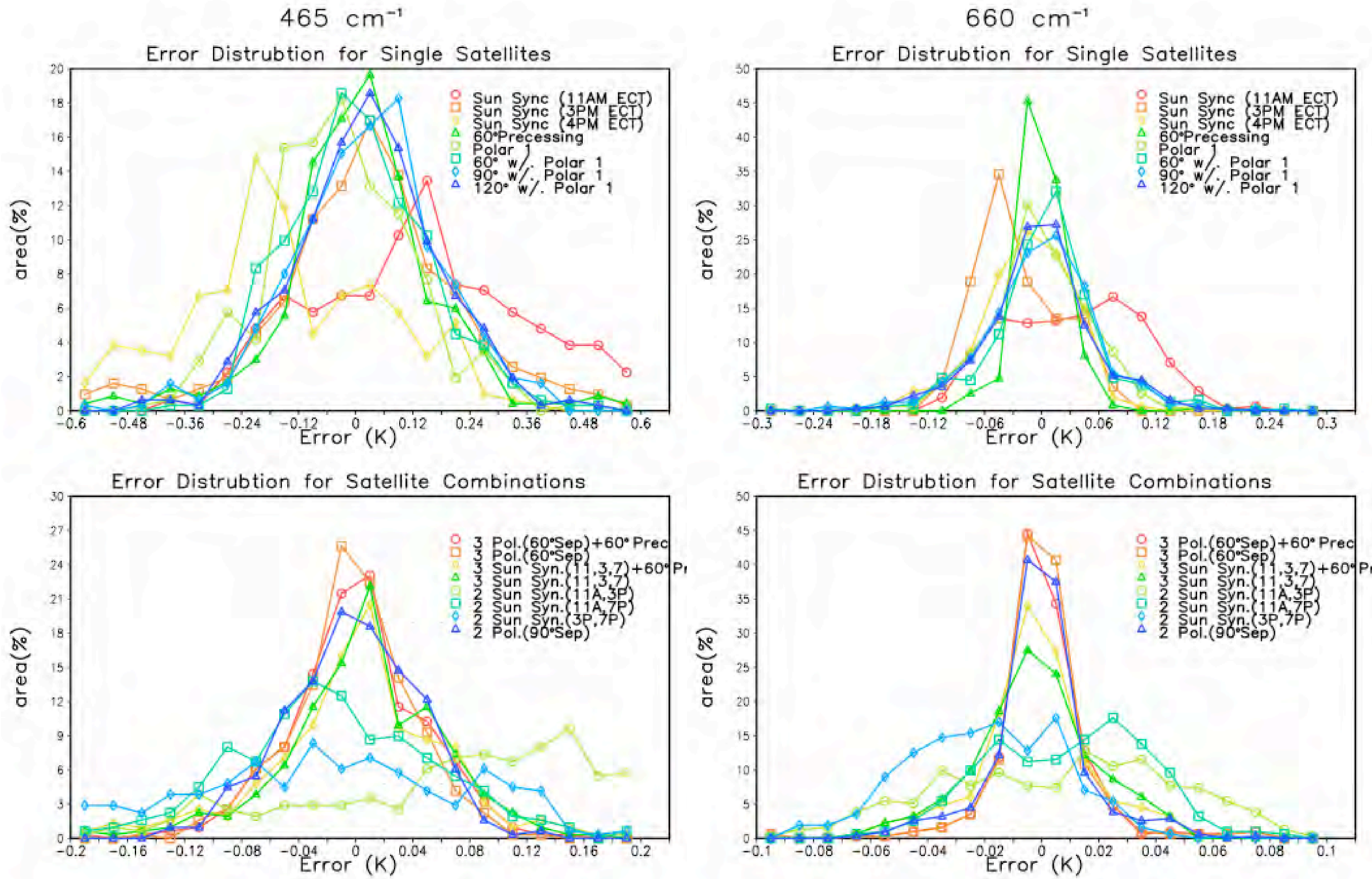
•90° inclination “true” polar orbits at various initial longitudes- observations rotate through 24 hours of local time twice over the year.

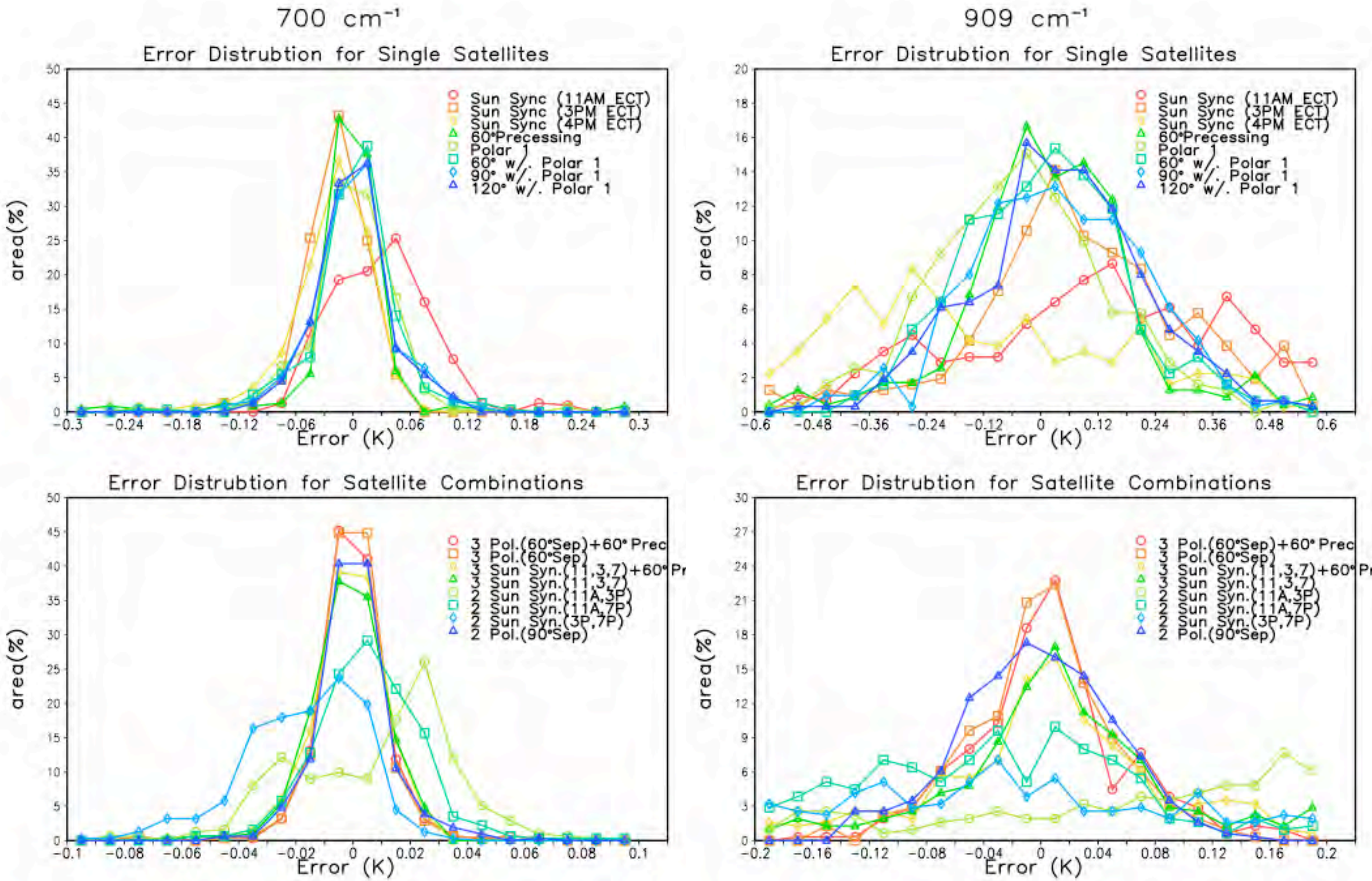
•Sun-synchronous polar orbits at a range of equator crossing times

•60° inclination orbits with more rapid precession- observations rotate through 24 hours of local time up to six times per year.

•Note that random errors from weather noise are essentially defeated for yearly means at 15x15 resolution, since we have ~9000 observations (for a 90 degree orbiter) per grid square. Diurnal sampling bias is the much more important error source.


Errors (*.01K) @909cm−1
Single Sats.
(i) at Sun Syn ECT 11 AM
(ii) at Sun Syn ECT 3 PM
(iii) at Sun Syn ECT 7 PM
(iv) at 60 deg. Precess.
(v) Polar 1
(vi) 60 deg. w/. Polar 1
(v) 90 deg. w/. Polar 1
(viii) 120 deg. w/. Polar 1
Errors (*.01K) for Sat. Combinations (909 cm−1)
3 polar @60 deg Separ + 60 deg Precess.
3 polar @60 deg Separn
3 Sun Sync.(11AM,3PM,7PM ECT) + 60 deg. Prec
3 Sun Sync.(11AM,3PM,7PM ECT)
2 Sun Sync.(11AM,3PM ECT)
2 Sun Sync.(11AM,7PM ECT)
2 Sun Sync.(3PM,7PM ECT)
2 Polar @90 deg Separn.
−55 −45 −35 −25 −15 −5
5 15 25 35 45 55 65
−55 −45 −35 −25 −15 −5
5 15 25 35 45 55 65


465 cm⁻¹
660 cm⁻¹
Error Distrubtion for Single Satellites
Sun Sync (11AM ECT)
Sun Sync (3PM ECT)
Sun Sync (4PM ECT)
60°Precessing
Polar 1
60° w/. Polar 1
90° w/. Polar 1
120° w/. Polar 1
area(%)
Error (K)
Error Distrubtion for Satellite Combinations
3 Pol.(60°Sep)+60° Prec
3 Pol.(60°Sep)
3 Sun Syn.(11,3,7)+60°Pr
3 Sun Syn.(11,3,7)
2 Sun Syn.(11A,3P)
2 Sun Syn.(11A,7P)
2 Sun Syn.(3P,7P)
2 Pol.(90°Sep)


700 cm⁻¹
909 cm⁻¹
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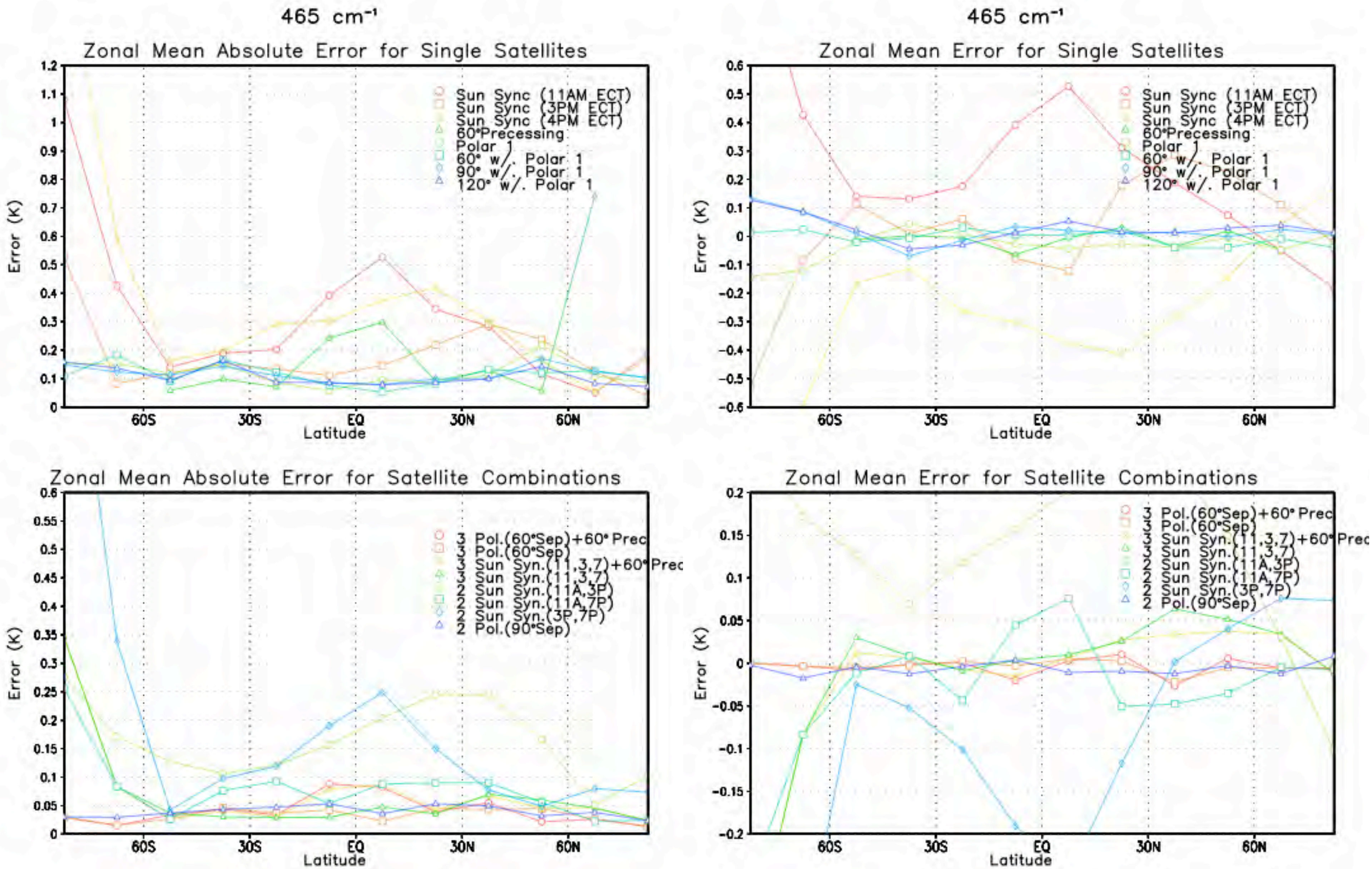
465 cm⁻¹
Zonal Mean Absolute Error for Single Satellites
Sun Sync (11AM ECT)
Sun Sync (3PM ECT)
Sun Sync (4PM ECT)
60°Precessing
Polar 1
60° w/. Polar 1
90° w/. Polar 1
120° w/. Polar 1
Error (K)
Latitude
60S
30S
EQ
30N
60N
465 cm⁻¹
Zonal Mean Error for Single Satellites
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Sun Sync (3PM ECT)
Sun Sync (4PM ECT)
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90° w/. Polar 1
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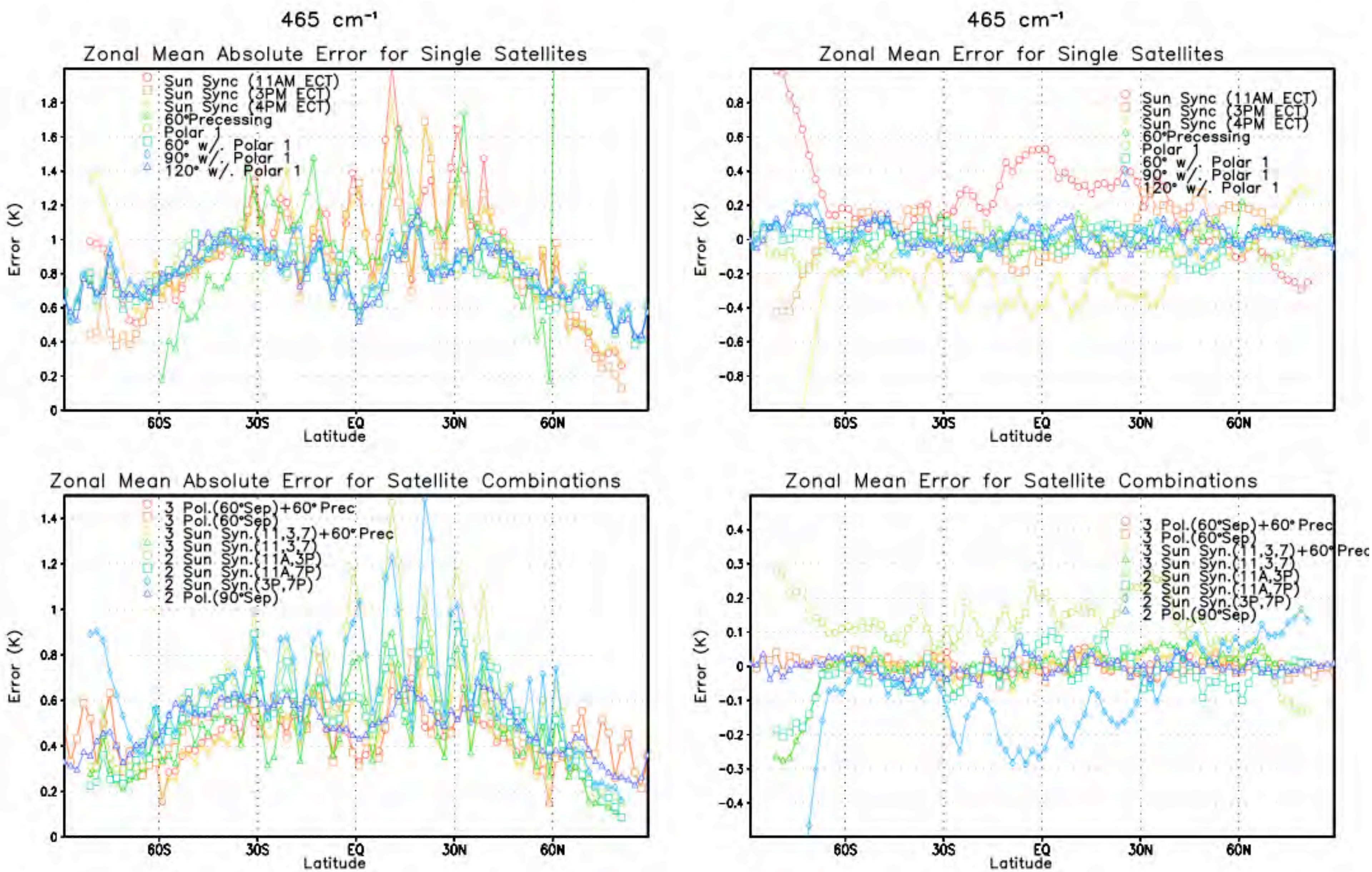
Latitude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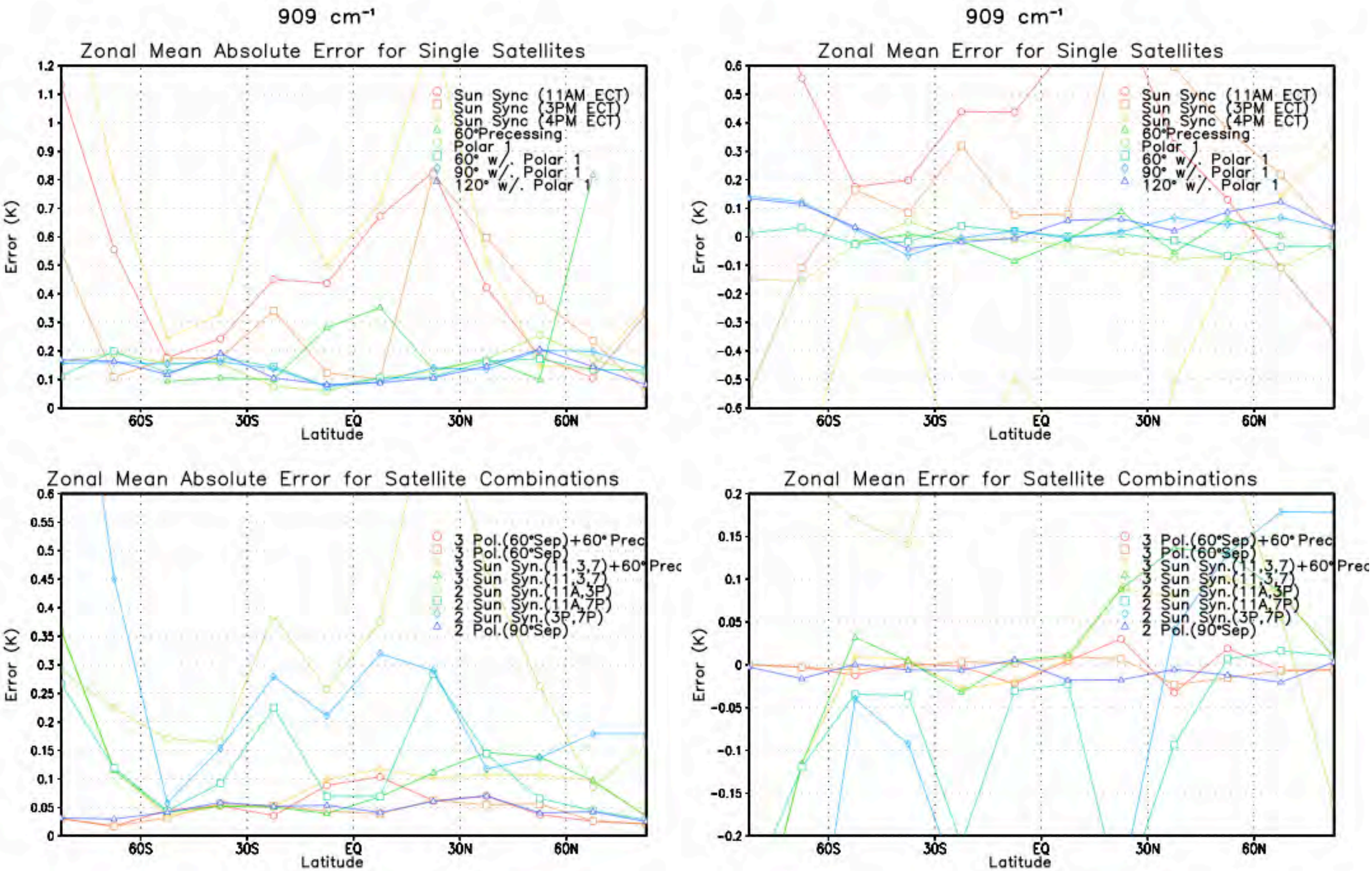
Zonal Mean Error for Satellite Combinations



909 cm⁻¹
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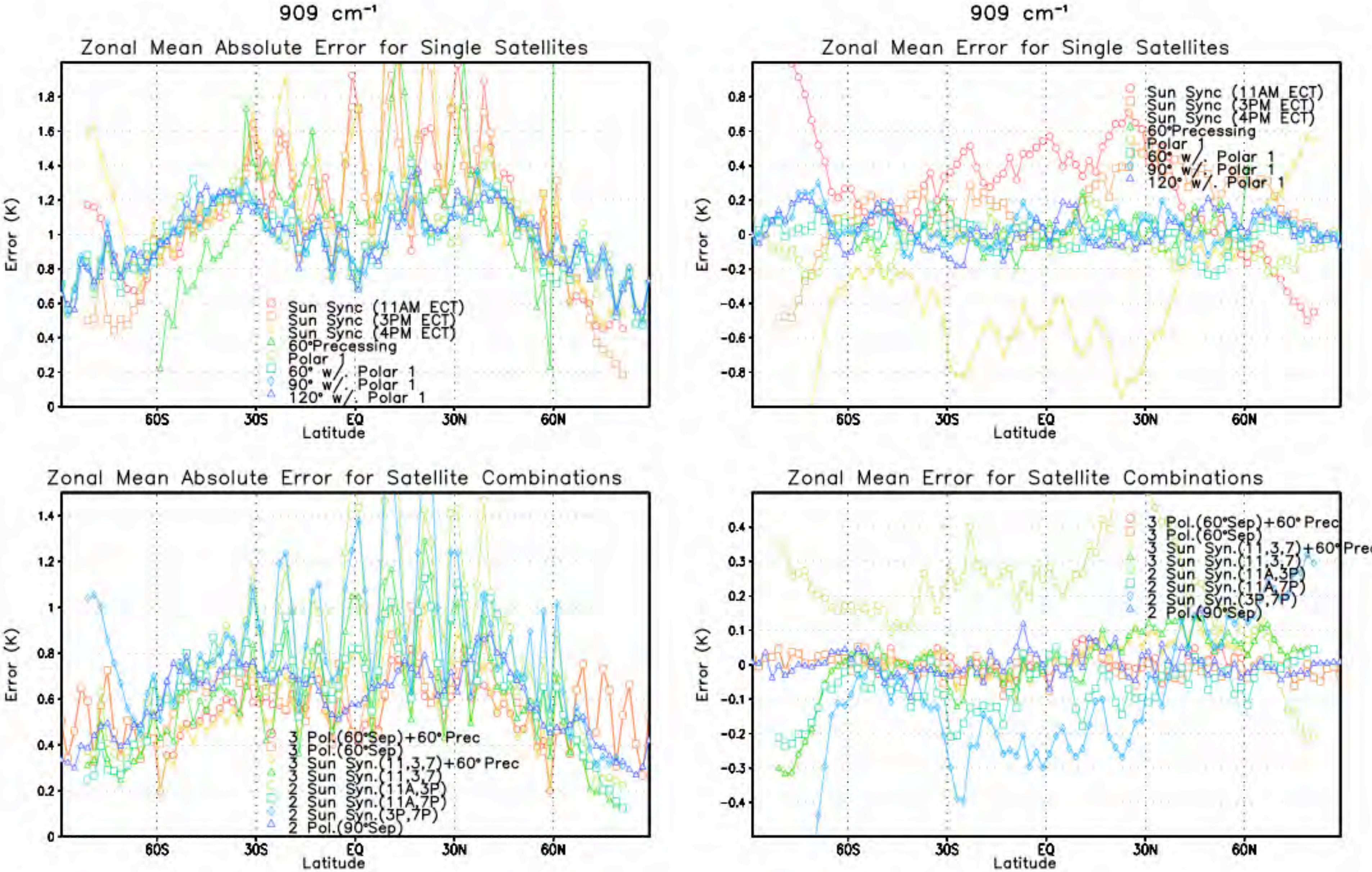
Zonal Mean Error for Satellite Combinations


909 cm⁻¹
Zonal Mean Absolute Error for Single Satellites
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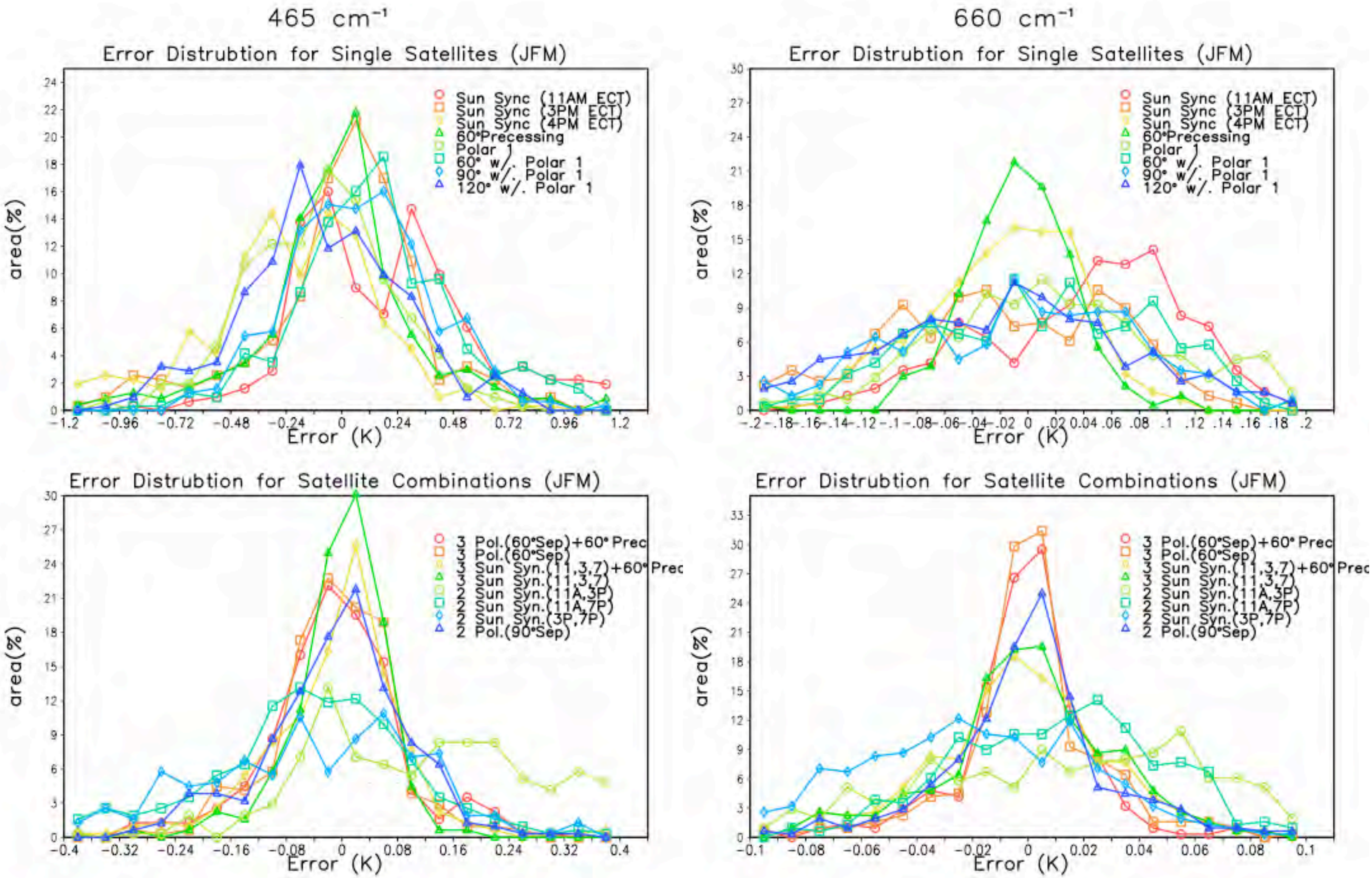
Zonal Mean Error for Satellite Combinations
Error (K)
Latitude


465 cm⁻¹
660 cm⁻¹
Error Distrubtion for Single Satellites (JFM)
Sun Sync (11AM ECT)
Sun Sync (3PM ECT)
Sun Sync (4PM ECT)
60°Precessing
Polar 1
60° w/. Polar 1
90° w/. Polar 1
120° w/. Polar 1
Error Distrubtion for Satellite Combinations (JFM)
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3 Pol.(60°Sep)
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3 Sun Syn.(11,3,7)
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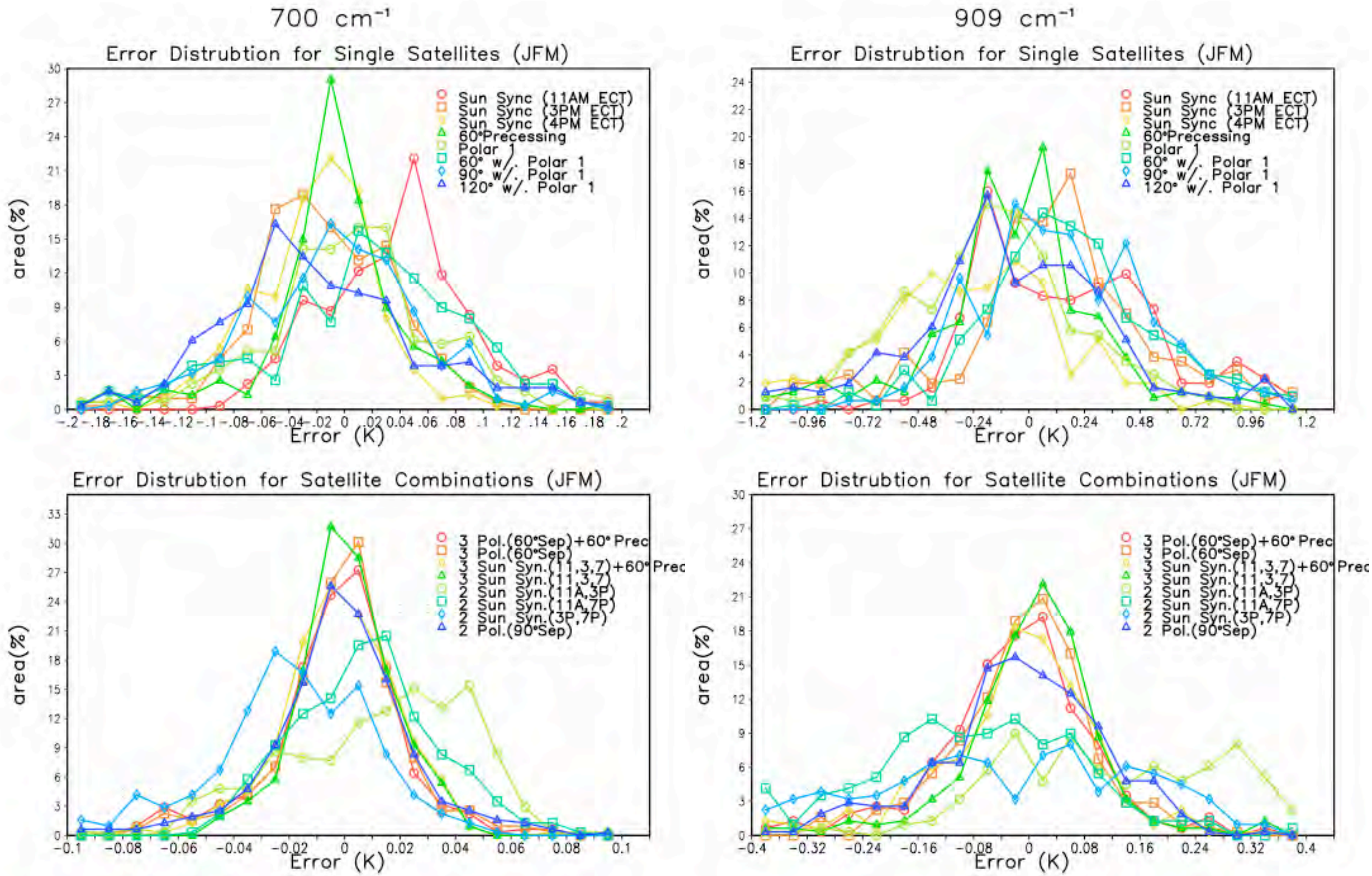
2 Sun Syn.(3P,7P)
2 Pol.(90°Sep)
area(%)
Error (K)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2 Sun Syn.(3P,7P)
2 Pol.(90°Sep)
area(%)
Error (K)

Conclusions

•A strategy of simultaneous nadir observation to calibrate satellites in different orbits allows about 1000 observations per calibrating satellite. Whether this is adequate depends on the magnitude of random errors for the calibration and target instruments.

•A calibrating instrument mounted on the same platform as the the target instrument would be a much better option for this purpose, since simultaneity and pointing errors could be eliminated and the number of observations maximized.

•A single observatory in a precessing orbit can achieve sampling errors in 15 degree grid boxes less than 0.1 K for brightness temperatures in the spectral regions that mostly sample the upper troposphere and lower stratosphere.

•In the mid-troposphere channels and in the window channel, a single precessing orbiter requires zonal averaging to reliably attain errors of less than 0.1 K.

•For multiple orbiters, precession has large advantages in establishing accurate mean radiances, because a configuration of several sun-synchronous orbiters must sample the diurnal cycle evenly. For instance, if there are initially three orbiters separated by 8 hours in equator crossing time, the loss of a single orbiter will greatly reduce the accuracy of the remaining two orbiters, assuming they maintain their station.

Discussion points

- Spectral Range
    - Is there anyone who wants to argue that we don't need the 200 - 600 cm^{-1} range?
- Spectral Resolution
- Spatial Resolution
- Temporal Resolution / Aquistion time